# KLM'S BORIC ACID RECLAMATION SYSTEM (BARS)

## AN UPDATE

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## ABSTRACT

KLM Technologies has implemented its Department of Energy Phase II Small Business Innovative Research (SBIR) demonstration program for a radioactive waste Boric Acid Reclamation System (BARS). Preliminary performance indicates enhanced treatment by the BARS technique over state of the art process methods for selective removal of silica and other impurities from borated water matrices. At optimal system recovery of 96-97 percent. BARS removes nominal levels of boric acid while achieving significant rejection for soluble silica and selective radioisotopes. This is indicative of superior performance compared to existing data governing standard boric acid process treatment in the presence of silica and other contaminants. Conventional technologies have also proven to be relatively expensive, utilizing costly chemically treated disposable resins for primary waste removal. The overall BARS program indicates substantial savings regarding off-site disposal costs based on reduced waste generation. Optimization of the BARS technology could have potential impact on conventional process technologies that are essentially non-selective in removal capacities.

Within the scope of the project, a variety of contaminated process streams and mixed radwaste sources have been evaluated at Northern States Power's Prairie Island Nuclear Generating Station. The boric acid feed streams originate from the following sources:

- Spent Fuel Pool (SFP)
- Chemical Volume and Control Systems (CVCS)
- Refueling Water Storage Tanks (RWSTs)
- Floor and Equipment Drains

The design of an advanced prototype BARS as an optimized process alternative was the result of KLM's initial Phase 1 SBIR program with the DOE in 1984 and 1985. The program was originally based on preliminary development efforts by key KLM participants in 1980, who assessed the applicability of membrane technology to refurbish and recycle contaminated boric acid streams.

A rather unique feature of BARS incorporates the development of a fully integrated computer-based artificial intelligence system for process control and monitoring. The system is based on the IBM/PC micro-computer, and includes "expert system" and a real-time data acquisition interface for collection of process data from pumps, filters, temperature control components and other process sensing and control devices.

## INTRODUCTION

Reduction of liquid radioactive waste generated by nuclear power plants is of primary importance when considering both storage and economic resources.

Today's economic scenario indicates that the optimization of volume reduction operational procedures would significantly reduce waste management costs, especially where burial penalties have become more severe (e.g. burial site closeout, volumetric restriction, substantial increase in burial costs, and constraints imposed by the demands on facilities having to meet the criteria of zero discharge). As a reaction to the increased cost burden imposed by final disposal, many nuclear plants are currently modifying their design and operating philosophies concerning liquid radwaste processing systems, in order to meet stricter environmental regulations, and to derive potential economic benefits by reducing the ever-increasing volumes of wastes that are produced. To effect these changes, modern practices in waste management and more efficient processing technologies have been employed.

One of the newer processes receiving serious attention in the nuclear industry involves the use of membranes consisting of ultrafiltration (UF) and reverse osmosis (RO) technologies. A major reason for the selection of membrane systems to treat liquid waste in nuclear power plants relates to the reduction of dilution water quantities. Although dilution constitutues acceptable treatment for nuclear laundry and shower water waste, newer generation plants, with cooling ponds or towers, may not have an adequate dilution water supply. Experience has indicated that floor drain waste is seldom able to meet economical prerequisite conductivity requirements (less than 100 µmhos/cm) for satisfying demineralizer specifications through the waste treatment system. The use of RO, however, is both technically and economically justified for processing water having conductivities of 200 μmhos/cm or greater.

The KLM Boric Acid Reclamation System (BARS) provides a way to, not only reduce the waste, but recycle the majority of the liquid for future use. The BARS utilizes RO membranes in order to process boric acid streams. The RO membranes allow the boric acid solution to permeate and be returned to the feed stream, while silica and other contaminants are rejected and sent to be processed as radwaste. The use of this technique, as opposed to "Feed and Bleed" on streams such as the spent fuel pool and the refueling water storage tanks, results in a reduction of waste produced, resins depleted, and replacement boric acid.

The BARS is capable of performing efficiently with little maintenance or operator attention. Pressure gauges, flow meters and various sensors continuously monitor performance conditions and isolate the system should parameters vary from pre-set limits. The BARS is also fitted to adjust both pH and temperature conditions should these parameters deviate outside the membrane's operating requirements.

The BARS is the result of a Phase II prototype project in which the engineering and processes were optimized to provide a reliable operating system. Pursuant to the DOE contract, KLM designed, fabricated, and executed a test program at Northern States Power's (NSP) Prairie Island Nuclear Generating Station located in Welch, Minnesota. NSP was chosen, after detailed review and meetings with two other potential sites, on the basis of schedule and design impact on the BARS prototype.

## SYSTEM DESCRIPTION

KLM BARS is a combination UF/RO system designed to recover boric acid from nuclear process and waste streams. Its major subsystems consists of:

- cartridge prefiltration (PF) system;
- clean-in-place (CIP) system that is automatically controlled to clean in place UF or UF/RO systems;
- air-cooled freon compressor chiller system; and
- free standing microprocessor control panel providing remote operation capability. All controls and electrical components are of NEMA-12 construction.

The UF system contains spiral-wound ultrafilter elements, contained within pressure housings constructed of 316 SS. The RO system contains hollow fiber reverse osmosis membranes contained in high pressure housings.

The multi-stage high pressure centrifugal pumps were used throughout the system. All wetted surface materials are of 316SS unless it was not practical or desirable to do so. The equipment is completely mounted on skids and integrates three progressive levels of filtration: prefiltration (PF), ultrafiltration (UF), and reverse osmosis (RO). The PF/UF/RO System is complete in all respects, including interface piping; NEMA electrical controls and enclosures; fused disconnects; transformer; motor starters; prefilters; pH controlling and recording equipment; chemical feed pumps; pressure pumps and motors; membrane pressure vessels; interconnecting piping, valving gauges and controls; continuous conductivity monitor; support frame skids, and miscellaneous other items to make it a complete and operating system. The BARS has a 30 gpm capacity under standard operating conditions. The system feed is provided by a transfer pump located on the prefiltration skid.

## SYSTEM OPERATION

### Machine Operation

The BARS can be operated in four different modes, two to process water and two to clean the system. The valves on the system are pneumatically actuated and will move to the correct position when an operating mode is chosen using the switch on the control panel. The BARS will process 28-34 gallons per minute depending on the mode used and the feed flow conditions.

#### Process Mode

In this mode, the BARS takes suction from the desired process stream. The process water is taken through a series of filtration processes including filtration, ultrafiltration and reverse osmosis. The process water is then returned to the original stream minus the contaminants which are directed as the concentrate down the floor drain into the aerated slump.

#### Process CIP Model

In this mode, the Clean-In-Place (CIP) tank provided with the system is filled with the desired process water. The water is taken through the successive steps of filtration, ultrafiltration and reverse osmosis. However, both the concentrate and permeate are returned to the CIP tank. There is an in-line valve after the reverse osmosis membranes that allows the permeate to be removed and the concentrate to be refiltered until the desired recovery is achieved.

#### UF CIP

This mode is a cleaning or flushing mode. The CIP tank is filled with a cleaning solution or with plain demineralized water. Instead of going through all three sets of filtration steps, the RO membranes are isolated allowing for selective cleaning of the ultrafiltration unit. There is increased flow through the UF membranes to cleanse away foulant buildup. All water is returned to the CIP tank.

#### UF/RO CIP Mode

This mode is also a cleaning mode but it includes the RO membrane. The proprietary cleaning solution is used as in the UF CIP mode.

### Alarms and Setpoints

There are several alarms on the system, some with fixed and others with variable setpoints. The alarms with fixed setpoints include all flow and pressure requirements needed for operation of the system. The variable alarm setpoints deal with things other than flows and pressures, including temperature, pH, conductivity and frequency of flushing. The variable setpoints have a preset minimum and maximum value to prevent the introduction of out of range values. A given setpoint for either fixed or variable alarms, may change depending on the mode of operation. These alarms are designed to safely and efficiently shut the system down in case of operating anomalies without requiring the need of operators.

## TECHNICAL OBJECTIVES AND APPROACH

The Phase II Design Development Program was directed toward a series of technical objectives enabling the preliminary BARS design to be engineered into a fully integrated process system, combining progressive levels of filtration, and consisting of three major subsystems referenced under "SYSTEM DESCRIPTION".

The positive inclination toward joint participation by operating nuclear utilities in the Phase II Demonstration Program was indicated through "Letters of Intent" from three PWR stations, and verified in the Phase I Final Report. This was a major step toward a successful implementation program, confirming the potential of BARS as a commercial product.

Pursuant to the written notification from DOE regarding the selection of KLM for a Phase II continuation of the BARS Program, KLM initiated efforts to screen the list of tentatively committed host site candidates, and made a final determination of Northern States Power's Prairie Island Station.

The major BARS Phase II technical objectives implemented at Prairie Island are:

- Design, fabricate, and factory test a 25 gpm full-scale prototype BARS.
- Install, startup, and optimize operation of the prototype BARS in an operating PWR.
- Support operations of the prototype BARS over an eleven (11) month period, including all necessary performance evaluations.
- Assure cost-effective optimal design, manufacturing, and operational features, while providing superior performance commensurate with a nuclear plant's design basis.

The technical approach taken to each objective follows:

### Objective 1

The design, fabrication, and factory "shake-down" testing required that a final design basis be confirmed and implemented. A preliminary system design was developed in the BARS Phase I Program and documented in the final report. This design was confirmed and finalized in combination with KLM project engineering and cognizant host site participants. The factory acceptance test of the system confirmed physically the system design. Subsequent to the development of a BARS final design specification, a purchase order was issued to the KLM selected membrane system vendor, reflecting the incorporation of a component chiller package to make BARS more flexible, and to alleviate the potential impact and dependency on plant cooling control systems. Further analysis was made during startup and operations in an ALARA assessment review to assure conformance with 10 CFR 20 and good ALARA practices.

### Objective 2

BARS installation, startup, and optimization were implemented at Northern States Power's Prairie Island Plant, following completion of fabrication and functional testing at the manufacturer's facility. Manpower requirements were primarily supplied by the host site for BARS installation, with KLM providing technical supervision. A plan was developed for determining the logistics governing the plant access route for the BARS placement and the key BARS interface connections to the plant facilities. A definitive BARS startup and optimization procedure, based upon an operations protocol, was also developed and exercised by KLM. KLM assumed the prime role during startup and optimization efforts, including efforts associated with training plant personnel. Operations, affecting both unit processes and system efficiency, were defined and confirmed through chemical quantification of performance parameters from each interstage process subsystem.

### Objective 3

During the Demonstration Program, KLM continued to supply support personnel to monitor on-site system operation and performance. BARS performance characteristics were analytically validated through an ongoing chemistry regime, utilizing the Station Laboratory facilities for work of a routine nature and off-site commercial laboratory services for non-routine support requirements. Selected parameters, governing performance assessment, consisted of the appropriate radiochemistry and stabilized chemistry species whenever possible.

KLM's integrated computer-based system linked to the microprocessor control system was designed to enhance the capability for real-time monitoring, remote process monitoring, control, and data reduction and handling. The system was developed to access performance data from pumps, filters, temperature control components, and other process sensing devices through a modern interface.

Feed stream characterization efforts were an integral part of KLM's on-going confirmatory program. Other tasks receiving continued attention over the extended cycle operation included:

- ALARA review analysis.
- Station personnel training.
- Economic analysis.

### Objective 4

Based on the database established on the previous page, the design and operating basis has been reviewed and optimized. After assuming that all functional design elements complied with applicable criteria the design is in the process of being reviewed from the perspective of quality assurance/quality control, performance, cost savings, and other pertinent features of a nuclear power plant environment.

### Summary

There are no anticipated problems or changes with respect to program objectives or technical approach. Consequences of delay of contract finalization led to problems with program continuity, affecting the BARS fabrication schedule and some increased equipment costs. The impact from contractual delays also affected the anticipated schedule for BARS factory fabrication and subsequent plant site installation, originally predicted on a January or February, 1986 installation time frame. This schedule was an integral element of Prairie Island's outage program, scheduled for March, 1986 and the "window of opportunity" for BARS installation.

Prairie Island agreed to make pertinent arrangements for installation, including preparation of the appropriate service interfaces to the system. These efforts included:

- Finalization of piping and electrical interface connections.

- Decontamination of allocated space.
- Review of ALARA engineering considerations.

NSP's original perception of plant retrofit policy was modified prior to installation. The plant's philosophy was reshaped concerning QA requirements governing the retrofit of BARS into the designated location of the process facility. This consequently resulted in several delays through installation and subsequent phased startup and operational protocols.

## CONCLUSION

The extensive test program carried out at NSP Prairie Island Nuclear Generating Station over the period of six months conclusively demonstrated the effectiveness of BARS to treat borated water streams in PWRs. During this time, BARS was subjected to a variety of PWR primary water streams containing a wide range of impurities. In every case, BARS effectively removed a significant amount of impurities while only removing a nominal amount of boric acid.

The major task performed by BARS at Prairie Island Plant was to lower the concentration of silica and other contaminants in the primary water pools (SFP, RWST, CVCS) in order to bring it within the operational chemistry specifications. It has been determined that BARS can perform this task of treating over 800,000 gallons of primary water in a period of about two months at substantial savings to the plant (over $500,000 for Prairie Island) over the conventional "Feed and Bleed" method. The savings to the plant rise dramatically when one considers using BARS to recycle otherwise waste boric acid in floor and equipment drains. BARS can also be used in conjunction with other waste treatment systems such as ion exchange and demineralizers as a pre-treatment system.

UF and RO have proven effective in the arena of waste water treatment. The innovative advances by KLM through the implementation of BARS, clearly demonstrate the viability to both design and operate an integrated system with minimal operator attention and maintenance requirements. Based on the demonstrated efficiency of BARS, a number of process and environmental advantages could be realized through its utilization in PWR nuclear plant operations. These include:

- Augmentation of existing plant capacities for processing variable waste loadings,
- Significant reduction of generated waste intended for off-site disposal, thereby extending burial site capacities,
- Recovery of costly chemicals (i.e., boric acid), thereby affecting discharge practice,
- Improvement of the maintenance of fuel integrity through process enhancement,
- Positive environmental conformance through the diminished release of low activity boric acid to large receiving streams (i.e., lakes and oceans),
- Advancement of the perception that effective plant waste management combines innovative and conventional process technologies.